Syllabus
FST 213. **Cheese Making Laboratory** -- 1 Credit
Term, Year
Meeting Day(s), Time, Place

Instructor: *TBD*
Office: *Location and office hours (if applicable)*
Phone: *Include personal number only if you are willing to release to students*
E-mail: *@tillamookbay.cc or @mail.tillamookbay.cc or other*

Course Description: Laboratory and field work to carry out basic cheese making procedures including fermentation, coagulation, cutting curd, cooking curd, and forming a finished cheese. Field trip required.

TBCC Email: TBCC will use electronic communication methods to conduct official and legal College business. Students are responsible to check their TBCC email and the TBCC student portal (MyTBCC) for information from the College.

Course Learning Outcomes:
1. Recognize common milk flavor defects.
2. Propose a method to stabilize milk proteins in an acid environment.
3. Understand the basic steps in cheese making. Be able to modify these basic steps to manipulate cheese composition.
4. Utilize petrifilm for environmental testing in a dairy processing facility.

Program Learning Outcomes:
- Fit into a business, agency, or academic setting and use concepts from agriculture and related fields to quantify and analyze issues and problems.
- Perform critical reasoning, perceive assumptions, and make judgments based on the basic principles of agriculture, natural resources, and related fields.
- Exhibit critical thinking skills when addressing issues in agriculture, natural resources, and related fields.

Institutional Learning Outcomes:
ILO #8. Analyze and evaluate information to address issues and solve problems.
ILO #9. Develop creative responses to ideas and information.
ILO #13 Demonstrate the knowledge, skills, and professional attitude necessary to enter and succeed in a defined profession or advanced academic program.

Competencies and Skills:
Milk Flavors
Smoothies
Queso Fresco
Mozzarella
Camembert
Gouda & Camembert
Gouda & Havarti
Dairy Microbiology

Instructional Materials: No textbook required. Readings will be assigned in classes.

Course Requirements:

Lab Assignments: Lab assignments will worth 10 points each and will be part of every lab. They will be due at the end of every class except in the first week.

Quizzes: Quizzes will be worth 10 points each. There will be 10 quizzes over the course of the term that will occur at the start of class and cover material from the previous week.

Lab Reports: Lab Reports will be worth 15 points each. There will be 10 lab reports over the course of the term that will be due at the start of class and cover material from the previous week.

Grading:

Lab Assignments = 10 points each = 100 points	30% of course grade
Quizzes = 10 points each = 100 points	30% of course grade
Lab Reports = 15 points each = 150 points	40% of course grade

A = 90-100% B = 80-89% C = 70-79% D = 60-69% F = 0-59%

ADA Statement:

Students who have a documented disability and require a classroom adjustment or accommodation should contact the Disabilities Coordinator/Career Education Advisor and provide the Approved Academic Accommodation form to the Instructor.

Academic Support Statement:

The Learning Center provides assistance to students with writing and math assignments. Hours are posted in the Library and classrooms. Peer tutors are available to assist students in a variety of subjects. Contact the Library for more information on peer tutoring.

Class Registration Statement:

Students may attend this course only if registered. Students who are unable to attend must drop the course through Student Services. To have tuition charges removed, the course must be dropped by the student before the drop with refund deadline in the Class Schedule. Students who never attend, or stop attending, without dropping may receive a NS, W, or F and will be required to pay for the course.

Grading Options Statement:

Students taking credit classes can choose between receiving traditional letter grades (A-F) and Pass/No Pass (P/NP) if the department has permitted both options for a course. *If you do not select a grading option*, you will automatically have the default grading option for that course. The default option is generally a letter grade, but could be pass/no pass. You can change your grading option through Student Services up until the eighth week of the term (for an eleven-week course). The only grading option available for each student is the one the student submitted during the selection timeframe. With the instructor's written permission, some courses may allow students to attend a course without receiving a grade or credit for the course. In order to Audit a class, you must return a signed form to Student Services. Your request must be processed by Student Services by the drop deadline for the course. You cannot opt into or out of (i.e. change your grading option from audit to a letter grade) after the drop deadline. Auditing a course does not satisfy requirements for entry into courses where prerequisites are specified.

Academic Integrity/Student Conduct Statement:
Students of Tillamook Bay Community College are expected to behave as responsible members of the College community while on campus and to be honest, ethical, and professional in their behavior and academic work. Tillamook Bay Community College strives to provide students with the knowledge, skills, judgment, and wisdom they need to function in society and careers as educated adults. Respect for others and behavior appropriate for a professional and educational environment is required of all. Behavior that violates the Code of Student Conduct, including any behavior disruptive to the educational process, is subject to disciplinary action. To falsify or fabricate the results of one's research; to present the words, ideas, data, or work of another as one's own; or to cheat on an examination is dishonest and corrupts the essential process of higher education. Academic dishonesty is also subject to disciplinary action. The full text of TBCC's Code of Student Conduct and Academic Integrity Policy can be found in the Student Rights and Responsibilities section of the TBCC Catalog.

Tentative Schedule by Week/Day and Date:

Wk 1. Introduction

Wk 2. Milk Flavors (Lab Assignment 1)
Quiz #1; Lab Report 1 Due

Wk 3. Smoothies (Lab Assignment 2)
Quiz #2; Lab Report 2 Due

Wk 4. Queso Fresco (Lab Assignment 3)
Quiz #3; Lab Report 3 Due

Wk 5. Mozzarella (Lab Assignment 4)
Quiz #4; Lab Report 4 Due

Wk 6. Camembert (Lab Assignment 5)
Quiz #5; Lab Report 5 Due

Wk 7. Gouda & Camembert (Lab Assignment 6)
Quiz #6; Lab Report 6 Due

Wk 8. Gouda & Havarti (Lab Assignment 7)
Quiz #7; Lab Report 7 Due

Wk 9. Gouda & Havarti Continued (Lab Assignment 8)
Quiz #8; Lab Report 8 Due

Wk 10. Dairy Microbiology (Lab Assignment 9)
Quiz #9; Lab Report 9 Due

Wk 11. Dairy Microbiology Continued (Lab Assignment 10)
Quiz #10; Lab Report 10 Due

Technology Statement: Most students need the following in order to take courses at TBCC. You are still encouraged to take this class, but if you lack technical or skill knowledge, please see me after class or make an appointment so that we can talk.

Technical (need):

1. Access to a computer (at home, school, or work) which you can use for extended periods of time.
2. Broadband internet access (cable modem, DSL, or other high speed).
3. Firefox 3.0 or later or Internet Explorer 7 or later. Safari and Chrome also work.
4. Permission/ability to install plug-ins or class software (e.g. Adobe Reader or Flash).
5. Highly recommended: up-to-date anti-virus software. If you are using your own computer check out the free anti-virus program at www.Avast.com.

Skills (ability):

1. Navigate web sites, including downloading and reading files from web sites.
2. Download and install software or plug-ins such as Adobe Reader or Flash.
3. Use email, including attaching and downloading documents/files from emails.
4. Save files in commonly used word processing formats (.doc, .docx, .rtf).
5. Copy and paste text and other items on a computer.
6. Save and retrieve documents and files on your computer.
7. Locate information on the internet using search engines.

Course Content and Outcomes Guide

DATE:
SUBMITTED BY: Emily Henry/Jeff Sherman/Lori Gates
COURSE NUMBER: **FST 213**
COURSE TITLE: **Cheese Making Laboratory**
CREDIT HOURS: **1**

LECTURE HOURS:
LECTURE/LAB HOURS:
LAB HOURS: 30

SPECIAL FEE:

COURSE DESCRIPTION and PREREQUISITES:
Laboratory and field work to carry out basic cheese making procedures including fermentation, coagulation, cutting curd, cooking curd, and forming a finished cheese. Field trip required.

ADDENDUM TO COURSE DESCRIPTION:
This course is intended to articulate to Oregon State University (OSU) as FST 213 Dairy Processing Laboratory (1 credit).

Supporting reading materials: University of Guelph dairy site at
http://www.uoguelph.ca/foodscience/dairy-science-and-technology

INTENDED COURSE OUTCOMES:
1. Recognize common milk flavor defects.
2. Propose a method to stabilize milk proteins in an acid environment.
3. Understand the basic steps in cheese making. Be able to modify these basic steps to manipulate cheese composition.
4. Utilize petrifilm for environmental testing in a dairy processing facility.

OUTCOME ASSESSMENT STRATEGIES:
Student learning outcomes will be evaluated through a variety of means, including but not limited to the following:
- Lab assignments
- Lab reports

COURSE CONTENT (Themes, Concepts, Issues) and SKILLS:
- Introduction
- Milk Flavors
- Smoothies
- Queso Fresco

- Mozzarella
- Camembert
- Gouda & Camembert
- Gouda & Havarti
- Dairy Microbiology

<table>
<tr><th colspan="2">OUTCOMES CROSSWALKS</th></tr>
<tr><td colspan="2">Identify which course outcome aligns to individual program learning outcomes. It is possible that all program outcomes may not be address by the course outcomes.</td></tr>
<tr><th>Course Outcomes</th><th>Program Outcomes</th></tr>
<tr><td colspan="2">Students who complete this course should be able to:</td></tr>
<tr><td>1. Recognize common milk flavor defects.</td><td rowspan="4">• Fit into a business, agency, or academic setting and use concepts from agriculture and related fields to quantify and analyze issues and problems.
• Perform critical reasoning, perceive assumptions, and make judgments based on the basic principles of agriculture, natural resources, and related fields.
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Lesson Plan: Milk Flavors

Objectives:

- Gain knowledge of most common milk flavor defects.
- Understand milk grading techniques
- Recognize common milk flavor defects by taste.

Readings:

Overview of milk defects:
https://www.uoguelph.ca/foodscience/dairy-science-and-technology/milk-grading-and-defects

Overview of milk grading techniques:
https://www.uoguelph.ca/foodscience/dairy-science-and-technology/milk-grading-and-defects/milk-grading-techniques

Overview of flavor characterization:
https://www.uoguelph.ca/foodscience/dairy-science-and-technology/milk-grading-and-defects/characterization-flavour-defects-adsa

Activities:

- Students will taste milk samples that have been modified in the lab to display most common milk defects. Students will then practice identifying these defects.

Milk Grading and Defects

The importance of milk grading lies in the fact that dairy products are only as good as the raw materials from which they were made. It is important that dairy personnel have a knowledge of sensory perception and evaluation techniques. The identification of off-flavours and desirable flavours, as well as knowledge of their likely cause, should enable the production of high quality milk, and subsequently, high quality dairy products.

An understanding of the principles of sensory evaluation are neccessary for grading. All five primary senses are used in the sensory evaluation of dairy products: sight, taste, smell, touch and sound. The greatest emphasis, however, is placed on taste and smell.

The Sense of Taste

Taste buds, or receptors, are chiefly on the upper surface of the tongue, but may also be present in the cheek and soft palates of young people. These buds, about 900 in number, must make contact with the flavouring agent before a taste sensation occurs. Saliva, of course, is essential in aiding this contact. There are four different types of nerve endings on the tongue which detect the four basic "mouth" flavours -**sweet, salt, sour, and bitter**. Samples must, therefore, be spread around in the mouth in order to make positive flavour identification. In addition to these basic tastes, the mouth also allows us to get such reactions as coolness, warmth, sweetness, astringency, etc.

The Sense of Smell

We are much more perceptive to the sense of smell than we are to taste. For instance, it is possible for an odouriferous material such as mercaptain to be detected in 20 billion parts of air. The centres of olfaction are located chiefly in the uppermost part of the nasal cavity. To be detectable by smell, a substance must dissolve at body temperature and be soluble in fat solvents.

Note: The sense of both taste and smell may become fatigued during steady use. A good judge does not try to examine more than one sample per minute. Rinsing the mouth with water between samples may help to restore sensitivity.

- Milk Grading Techniques
- Characterization of Flavour Defects - ADSA

‹ Milk Biosynthesis up Milk Grading Techniques ›

- Ice Cream
- Cheese Making Technology

Milk Grading Techniques

Temperature should be between 60-70° F (15.5-21° C) so that any odour present may be detected readily by sniffing the container. Also, we want a temperature rise when taking the sample into the mouth; this serves to volatize any notable constituents.

Noting the odour by placing the nose directly over the container immediately after shaking and taking a full "whiff" of air. Any off odour present may be noted.

Need to make sure we have a representative sample; mixing and agitation are important.

Agitation leaves a thin film of milk on the inner surface which tends to evaporate giving off odour if present.

During sampling, take a generous sip, roll about the mouth, note flavour sensation, and expectorate. Swallowing milk is a poor practice.

Can enhance the after-taste by drawing a breath of fresh air slowly through the mouth and then exhale slowly through the nose. With this practice, even faint odours can be noted.

Milk has a flavour defect if it has an odour, a foretaste or an aftertaste, or does not leave the mouth in a clean, sweet, pleasant condition after tasting.

‹ Milk Grading and Defects up Characterization of Flavour Defects - ADSA ›

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- Cheese Making Technology

Characterization of Flavour Defects - ADSA

Lipolytic or Hydrolytic rancidity

Rancidity arises from the hydrolysis of milkfat by an enzyme called the lipoprotein lipase (LPL). The flavour is due to the short chain fatty acids produced, particularly **butyric acid**. LPL can be indigenous or bacterial. It is active at the fat/water interface but is ineffective unless the fat globule membrane is damaged or weakened. This may occur through agitation, and/or foaming, and pumping. For this reason, homogenized milk is subject to rapid lipolysis unless lipase is destroyed by heating first; the enzyme (protein) is denatured at 55-60° C. Therefore, always homogenize milk immediately before or after pasteurization and avoid mixing new and homogenized milk because it leads to rapid rancidity.

Some cows can produce spontaneous lipolysis from reacting to something indigenous to the milk. Late lactation, mastitis, hay and grain ratio diets (more so than fresh forage or silage), and low yielding cows are more suseptible.

Lipolysis can be detected by measuring the acid degree value which determines the presence of free fatty acids. Lipolytic or hydrolytic rancidity is distinct from oxidative rancidity, but frequently in other fat industries, rancid is used to mean oxidative rancidity; in dairy, rancidity means lipolysis.

Characterized: soapy, blue-cheese like aroma, slightly bitter, foul, pronounced aftertaste, does not clear up readily

Oxidation

Milk fat oxidation is catalysed by copper and certain other metals with oxygen and air. This leads to an autooxidation reaction consisting of initiation, propagation, termination.

RH --- R + H **initiation** - free radical

R + O2 ---- RO2 **propagation**

RO2 + RH --- ROOH + R

R + R --- R2 **termination**

R + RO2 --- RO2R

It is usually initiated in the phospholipid of the fat globule membrane. Propagation then occurs in triglycerides, primarily double bonds of unsaturated fatty acids. During propagation, peroxide derivatives of fatty acids accumulate. These undergo further reactions to form carbonyls, of which some, like aldehydes and ketones, have strong flavours. Dry feed, late lactation, added copper or other metals, lack of vit E (tocopherol) or selenium (natural antioxidates) in the diet all lead to spontaneous oxidation. It can be a real problem especially in winter. Exposure to metals during processing can also contribute.

Characterized: metallic, wet cardboard, oily, tallowy, chalky; mouth usually perceives a puckery or astringent feel

Sunlight

Often confused with oxidized, this defect is caused by UV-rays from sunlight or flourescent lighting catalyzing oxidation in unprotected milk. Photo-oxidation activates riboflavin which is responsible for catalyzing the conversion of methionine to methanal. It is, therefore, a protein reaction rather than a lipid reaction. However, the end product flavour notes are similar but tends to diminish after storage of several days.

Characterized: burnt-protein or burnt-feathers-like, "medicinal"-like flavour

Cooked

This defect is a function of the time-temperature of heating and especially the presence of any "burn-on" action of heat on certain proteins, particulary whey proteins. Whey proteins are a source of sulfide bonds which form sulfhydryl groups that contribute to the flavour. The defect is most obvious immediately after heating but dissipates within 1 or 2 days.

Characterized: slightly cooked or nutty-like to scorched or caramelized

Transmitted flavours

Cows are particulary bad for transmitting flavours through milk and milk is equally as susceptible to pick-up of off flavours in storage. Feed flavours and green grass can be problems so it is necessary to remove cows from feed 2-4 hrs before milking. Weeds, garlic/onion, and dandelions can tranfer flavours to the milk and even subsequent products such as butter. Barny flavours can be picked up in the milk if there is poor ventilation and the barn is not properly cleared and cows breathe the air. These flavours are volatile so can be driven off through vacuum de-aeration.

Characterization: hay/silage, cowy/barny

Microbial

There are many flavour defects of dairy products that may be caused by bacteria, yeasts, or moulds. In raw milk the high acid/sour flavour is caused by the growth of lactic acid bacteria which ferment lactose. It is less common today due to change in raw milk microflora. In both raw or processed milk, fruity flavours may arise due to psychrotrophs such as *Pseudomonas fragi*. **Bitter or putrid** flavours are caused by psychrotrophic bacteria which produce protease. It is the proteolytic action of protease that usually causes spoilage in milk. **Malty** flavours are caused by *S.lactis* var. *maltigenes* and is characterized by a corn flakes type flavour. Although more of a tactile defect, **ropy** milk is also caused by bacteria, specifically those which produce exopolysaccharides.

Miscellaneous Defects

- astringent
- chalky
- chemical/medicinal - disease - associated or adulteration
- flat - adulteration (water)
- foreign
- salty - disease associated
- bitter - adulteration

More information on off-flavours in milk can be found in Clarke et al.

Milk flavour is graded on a score of one to 10. Some flavour defects, even if only slightly present, can decrease the score drastically. The following are suggested flavour scores for milk with designated intensities of flavour defects.

Flavour Criticisms	Intensity of Defect		
	Slight	Definite	Pronounced
Astringent	8	7	5
Barny	7	5	3
Bitter	7	5	3
Cooked	9	8	6
Cowy	6	4	1
Feed	9	7	5
Flat	9	8	7
Foreign	5	3	0
Garlic/onion	5	3	1
High acid	3	1	0
Bacterial	5	3	0
Lacks Freshness	7	5	3
Malty	7	5	3
Oxidized	7	5	3
Rancid	7	5	3
Salty	8	6	4
Unclean	7	5	3

‹ Milk Grading Techniques up Dairy Chemistry and Physics ›

Assessment: Cheese Identification Quiz

You will be given five (5) cheese samples to identify. You will get 2 points for each correctly identified cheese (10 points total).
Name_______________________________________
Date____

<u>List of Possible Cheeses:</u>

White Cheeses	**Dark Cheeses**
Brick	Blue
Brie	Cheddar—Mild
Cream	Cheddar—Sharp
Monterey Jack	Colby
Mozzarella	Gouda
Munster	Processed American
Provolone	
Swiss	

Cheese Sample #	**Cheese Identity**
1	
2	
3	
4	
5	

Lesson Plan: Mozzarella

Objectives:

- Gain knowledge of mozzarella, including differences between American and Italian mozzarellas.
- Understand and practice the process of making mozzarella.
- Demonstrate correct sanitation processes.

Readings:

Barbano, D.M, J.J. Yun, and P.S. Kindstedt. 1994. Mozzarella Cheese Making by a Stirred Curd, No Brine Procedure. Journal of Dairy Science: 77(9).
http://download.journals.elsevierhealth.com/pdfs/journals/0022-0302/PIIS0022030294772118.pdf

Activities:

- Students will make American mozzarella cheese.

OUR INDUSTRY TODAY

Mozzarella Cheese Making by a Stirred Curd, No Brine Procedure[1]

DAVID M. BARBANO, J. JOSEPH YUN, and PAUL S. KINDSTEDT[2]
Northeast Dairy Foods Research Center
Department of Food Science
Cornell University
Ithaca, NY 14853

ABSTRACT

To eliminate the problems associated with brine salting, a milled curd, no brine method for making low moisture, part-skim Mozzarella cheese was developed and reported previously. The method produced cheese with homogeneous chemical composition and desirable functional characteristics. However, the moisture content of the low moisture, part-skim Mozzarella cheese from this method was too low (about 44 to 45%). To increase cheese moisture content, a stirred curd, no brine Mozzarella cheese-making process was developed. With this new method, cheese moisture content can be controlled within the range of 45 to 52% while achieving normal salt, pH, and fat content on a dry weight basis. Changes in proteolysis and functional properties during the refrigerated storage were similar to those for commercial cheeses.
(**Key words**: moisture, Mozzarella, no brine, stirred curd)

Abbreviation key: **LMPS** = low moisture, part-skim; **MCNB** = milled curd, no brine; **SCNB** = stirred curd, no brine.

INTRODUCTION

Problems with Brine Salting

Brine salting produces Mozzarella cheese with heterogeneous chemical composition (12). Differences in block size and shape cause different patterns of nonhomogeneity (9). Variation in chemical composition, especially gradients of salt and moisture concentration within each block of cheese, can affect proteolysis and functional properties during aging (12). Thus, representative sampling of cheese and correct interpretation of results are difficult when cheese is brine salted (5, 12).

Other problems are associated with brine salting. Open brine systems can be a source of microbial contamination of cheese by yeast, mold, and bacteria. Commercial systems exist for cleaning and sanitizing brine using UV light, filtration, and pasteurization. However, the highly corrosive nature of saturated brine makes these systems difficult to maintain. Cleaning the brine and maintenance of the equipment used for that purpose increase cheese manufacturing costs. Ultimately, when the brine is no longer usable, the disposal of large volumes of saturated brine can be an environmental problem (26).

Need for a No Brine Cheese-Making Method

Efforts to improve salting methods for Mozzarella cheese (8, 17, 21) have involved addition or injection of salt (solid or liquid) during the stretching of the Mozzarella cheese. All of the salt cannot be easily incorporated at this point in the process because the high concentration of salt in the mixer water (about 10 to 12%, wt/wt) causes the curd to float in the mixer. Additional difficulties include high fat loss from the cheese in the mixer and low cheese moisture. Currently, some companies apply a portion of the salt to the curd or in the mixer prior to the brining step; others continue to rely on brine as the only means of adding salt to Mozzarella. Thus, most commercial

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[1]Use of trade names, names of ingredient, and identification of specific models of equipment is for scientific clarity and does not constitute any endorsement of product by authors, Cornell University, University of Vermont, or Northeast Dairy Foods Research Center.

[2]Department of Food and Animal Science, University of Vermont, Burlington 05405.

Mozzarella cheese manufacturers still use brine salting.

In our previous work, we developed a milled curd, no brine (**MCNB**) method for making Mozzarella cheese (27). The MCNB method produced cheese with homogeneous chemical composition and desirable functional characteristics (27, 28). However, the moisture content of the Mozzarella cheese from the MCNB method was too low, about 44 to 45%, which is close to the moisture minimum requirement of 45% for low moisture, part-skim (**LMPS**) Mozzarella (7) and which results in low cheese yield. Therefore, the objective of this research was to develop a no brine cheesemaking method that could achieve cheese moisture in the range of 45 to 52%.

MATERIALS AND METHODS

Overall Experimental Approach

One of the approaches used to increase cheese moisture was to shorten the total time for the cheese-making process, thus decreasing the time for syneresis and increasing the moisture content of the cheese. To shorten total cheese-making time, the amount of culture was increased for faster acid development.

Under commercial cheese-making conditions, the milling step is very time-consuming and limits how much the manufacturing time can be shortened. To simplify further the cheese-making process, especially to accommodate the shorter cheese-making time, a stirred curd method (continuous stirring of curd after draw) was used instead of packing, cheddaring, and milling (Figure 1). Nilson and LaClair (19) explored this approach to Mozzarella cheese making but did not consider elimination of brine salting.

Adjustments were also made in the salt usage in dry salting and in preparation of stretching water to minimize the moisture loss during dry salting and stretching while maintaining the salt content of the cheese at 1.5 to 2.0%. After many preliminary trials, a cheesemaking method was established. The chemical composition of the fresh cheese was determined on d 2, and the age-related proteolysis and functional property changes were monitored during 50 d of storage at 4°C.

Stirred Curd, No Brine Method

Raw skim milk and raw cream were obtained from the Cornell University dairy plant and combined to obtain the desired casein to fat ratio for cheese making. The milk was pasteurized (model Universal Pilot Plant; PMS Processing Machinery and Supply Co., Philadelphia, PA) at 72°C for 16 s, cooled to 4°C, and stored overnight at 4°C. The next day, the milk (about 180 kg per vat) was poured into a cheese vat (model 4MX; Kusel Equipment Co., Watertown, WI) and heated to 38°C.

Direct-to-vat frozen starter cultures, Thermococcus C120® (*Streptococcus salivarius* ssp. *thermophilus*) and Thermorod R160® (*Lactobacillus delbrueckii* ssp. *bulgaricus*) from Rhône-Poulenc (Madison, WI) were prepared as previously described (27). Equal amounts of both cultures were added (.50 ml of each culture/kg of milk), and the milk was ripened for 60 min at 38°C. During ripening, milk pH decreased from 6.63 to 6.44. At the end of ripening, chymosin derived by fermentation (Chymax®, double strength; Pfizer Inc., Milwaukee, WI) was added (.10 ml/kg of milk). After a 30-min setting time, the milk coagulum was cut with a 1.2-cm wire knife and allowed to heal for 5 min.

After healing, the curds were stirred for 10 min at 38°C or until the whey pH reached 6.20, and then the whey was drained. No heating step was used in the cheese vat. The only heat requirement was to maintain the temperature at 38°C. The curd was stirred during and after draining the whey until the curd pH reached 5.50. On average, 94 min were required from coagulant addition to the time that curd pH reached 5.50 and an additional 20 min for the salting. Salt was added (total 2.2%, wt/wt) in three equal applications (with 5-min intervals between applications and 5 extra min for mellowing) while the curd was continuously stirred. Curd temperature was maintained at 38°C during salting and stirring. When the salting was finished and the curd was ready for stretching, the pH of the salted curd was about 5.30. The pH of the curd at salting can be adjusted to achieve a range of desired pH at stretching.

A twin-screw, pilot-scale Mozzarella mixer (model 640; Stainless Steel Fabricating, Columbus, WI) was used to stretch the curd (27). Salted curd was fed into the pilot-scale

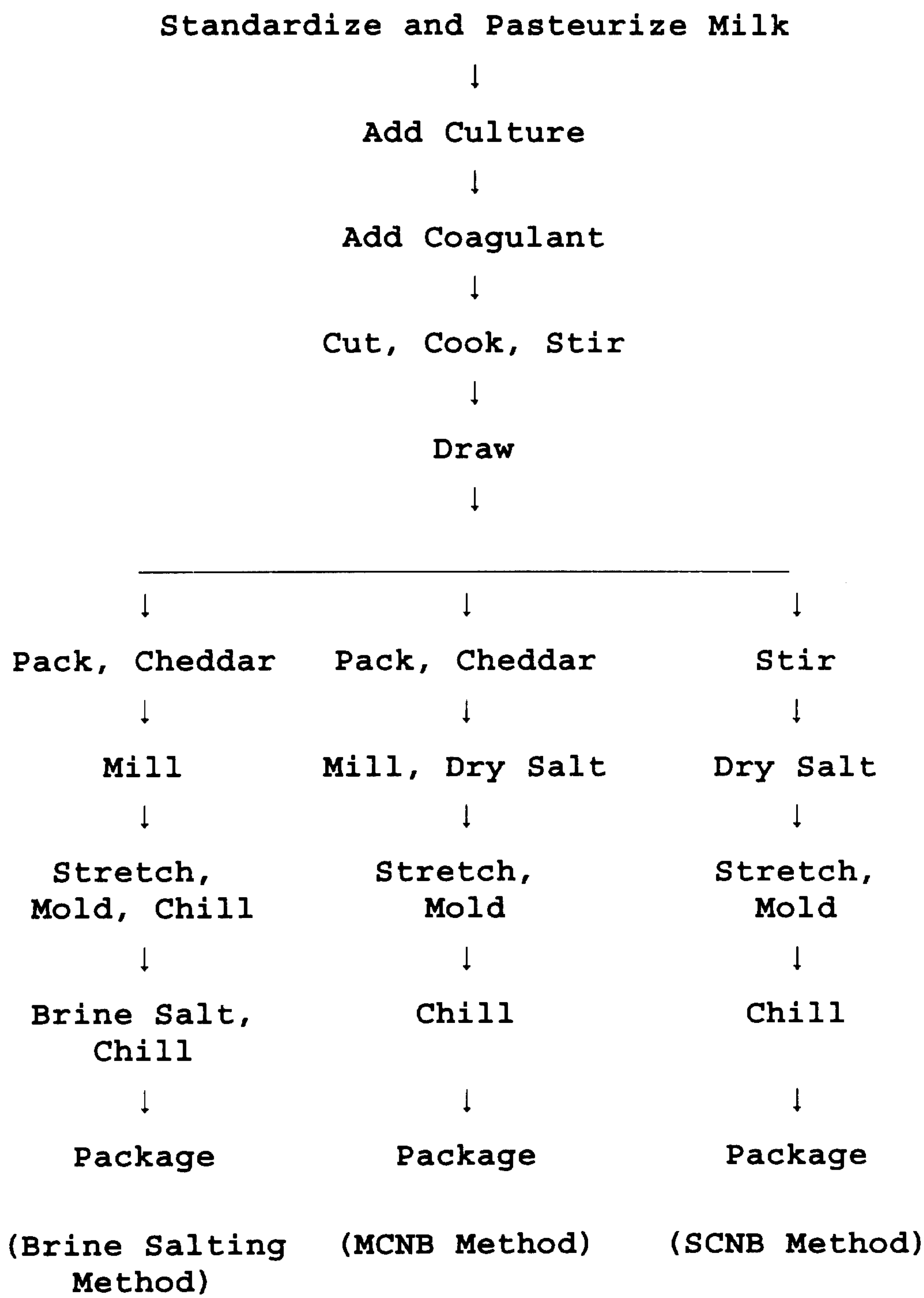

Figure 1. Flow diagram of three Mozzarella cheese-making methods: brine salting; milled curd, no brine (MCNB); and stirred curd, no brine (SCNB) methods.

mixer (about 2 kg/min) and was stretched in hot (57°C) circulating water containing 6% salt (wt/wt). To prepare the circulating hot salt water (35 kg), the salt solution was heated to 57°C in a steam-jacketed kettle and then poured into the mixer about 3 min before curd was added. The temperatures of circulating salt water and the mixer jacket were maintained at 57°C. The screw speed of the mixer was set at 50% of its full speed (ca. 12 rpm), and completion of stretching took about 10 min for about 15 kg of salted curd.

Stretched cheese was extruded into stainless steel, cylindrical tubes (7.5 cm diameter × 30 cm long). The first 1 kg of extruded cheese for each vat was removed and discarded. Tubes filled with 1.4 kg of cheese were placed in ice water. After 60 min of cooling, the internal temperature of the cheese reached 20°C. The cheese was removed from the tube and vacuum packaged (Multi Vac model 160; Koch, Kansas City, MO) in a barrier bag (model B150; Cryovac, Duncan, SC) and stored at 4°C. Eight full cylinders of cheese were made per vat. The third and fourth cylinders (sequence of extrusion) were used for chemical analyses; the second and fifth cylinders were used for functionality tests.

Analyses

Chemical Composition. Changes in titratable acidity of milk and whey (23) and pH of milk, whey, and curd were monitored during cheese making. A Xerolyt electrode (model HA405; Ingold Electrode, Wilmington, MA) and Accumet pH meter (model 915; Fisher Scientific, Springfield, NJ) were used for pH measurements. Temperature of whey and curd during pH measurement was 38°C. The electrode was immersed in 3 *M* KCl storage solution at 38°C between pH measurements to improve their stability. The pH meter was calibrated with reference solutions (Fisher Scientific) for pH 4 (SB107-500) and pH 7 (SB101-500) at 38°C using temperature correction coefficients provided by the manufacturer of the buffers.

Fat contents of milk (1), cream (1), whey (23), and cheese (23) were determined using Babcock tests. All nitrogen determinations were performed by Kjeldahl (2). Percentages of nitrogen from the analyses of noncasein nitrogen (10) and total nitrogen (2) were multiplied by 6.38 to give milk protein equivalents. Total nitrogen and noncasein nitrogen were measured in triplicate. All other chemical analyses, except cheese moisture, were performed in duplicate. Cheese moisture was determined gravimetrically, in quadruplicate, by drying 2 g of ground cheese at 100°C in a forced-air oven (model OV-490A-2; Blue M, Blue Island, IL) for 24 h (23). Calcium concentration in cheese was determined by complexometric titration (13).

Storage Tests. All tests during storage were performed after 3, 8, 15, 21, 29, and 50 d of refrigerated storage at 4°C. To determine the titratable acidity of cheese (1), 10 g of cheese and 95 ml of 60°C distilled water were mixed in a blender (Waring, New Hartford, CT) for 30 s, 25 ml of the filtrate (filter paper number 1; Whatman Ltd., Maidstone, England) were titrated with .1*N* NaOH, and the acid content of the cheese was calculated as a percentage of lactic acid. Before the pH of cheese was measured, the samples and buffers were tempered to 20°C.

The amount of nitrogen that was soluble in acetate buffer at pH 4.6 and in 12% TCA was determined to measure proteolysis (4) and expressed as a percentage of total nitrogen content of cheese.

Texture profile analysis (3) of Mozzarella cheese was performed in quadruplicate using the Instron Universal Testing Machine (model TM; Instron Corp., Canton, MA). Cheese meltability was measured in quadruplicate by a modified Schreiber test (16). Apparent viscosity of melted Mozzarella cheese was measured in duplicate by helical viscometry (11). Free oil of Mozzarella cheese was measured in duplicate using the centrifugation method (14). Detailed explanations of the testing methods for functional properties have been reported (11, 14, 28).

For the browning test, an aluminum pan coated with Teflon® (Ekco, Manotowoc, WI) with 12 round sample wells (7 cm in diameter and 3 cm high) was used. Ground cheese samples were weighed (20 g) into each sample well in the pan and allowed to warm to room temperature (20°C) before heating. The pan containing the samples was put into a preheated forced-air oven (model OV-490A-2; Blue M) at 100°C for 1 h. Cheese samples were cooled to room temperature. The melted cheese samples had fused into solid disks and were removed from the sample well. Color was measured using a MacBeth Color-Eye® spectrophotometer (model 2020PC; Optiview, Macbeth, Newburgh, NY) that was calibrated by using a white calibration tile (number H38060). Cheese samples were placed in a specially designed sample holder and put in the view port with a large area view setting (25.4 mm in diameter). Three color indices (22), L (light to dark), a (red to green), and b (yellow to blue) values, were taken for each sample in duplicate.

RESULTS AND DISCUSSION

Preliminary Trials

During the preliminary trials, different amounts of culture were used to change the cheese-making time. The cooking protocol of increasing temperature from 36 to 41°C in 15 min was used in some trials. In other trials, the temperature of milk and curd was maintained at 38°C throughout the cheese making. Salt usage was varied in dry salting and in water for stretching.

The time from addition of coagulant to stretching was varied from 170 to 63 min, depending mainly on the amount of culture added to milk. The key conclusion from the preliminary trials was that, in general, the moisture content of the cheese was inversely related to total cheese-making time and ranged from 46.8 to 50.7%. Moisture and fat on a dry weight basis of the resulting cheeses were all within the legal range for LMPS Mozzarella cheese (7). The pH and salt concentration of these cheeses were within the range for commercial cheeses (18).

Cheese-Making Method Performance

After the preliminary trials, a stirred curd, no brine (**SCNB**) cheese-making method was established. Then, Mozzarella cheese was made on 3 different d using three different batches of milk. The average fat, protein, and casein contents of milks were ($\overline{X}$ ± SD) 2.09 ± .08, 3.10 ± .06, and 2.37 ± .05%, respectively.

Effect on Moisture. The previous MCNB Mozzarella cheese-making method produced uniform cheese composition within the block (27). However, the mean moisture of the cheese from the MCNB cheese making was below the legal minimum of 45% for LMPS Mozzarella cheese (Table 1) (7). Moisture content of the curd prior to salting was about 50%. Much of the loss in moisture (about 4%) occurred during dry salting. Moisture loss during stretching ranged from 1 to 2%.

TABLE 1. Chemical composition (n = 3) of Mozzarella cheeses made using two different cheese making methods.

	Method			
Component	Milled curd, no brine		Stirred curd, no brine	
	$\overline{X}$	SD	$\overline{X}$	SD
pH	5.16	.02	5.22	.01
Moisture, %	44.61	.14	48.40	.65
Fat, %	21.25	.20	19.71	.36
FDB,[1] %	38.33	.45	38.20	1.07
Protein, %	27.99	.17	26.20	.99
M:P[2]	1.59	.01	1.85	.10
Salt, %	1.45	.04	1.76	.08
S:M,[3] %	3.26	.10	3.65	.21
Calcium, %	.83	.03	.69	.04
Calcium (% of P),[4] %	2.97	.08	2.64	.14

[1]Fat content on a dry weight basis.

[2]Ratio of moisture to protein.

[3]Ratio of salt to moisture in the cheese.

[4]Calcium as a percentage of protein content of the cheese.

With the new SCNB cheese-making method, the chemical composition was within the target range for LMPS Mozzarella (Table 1). The mean final moisture content was in the middle of the allowed range (i.e., 45 to 52%) (7). The final cheese moisture was about 4% higher for the SCNB method than the MCNB method because the moisture content of salted curd at the beginning of the stretching step was about 4% higher (data not shown). The higher moisture in the salted curd was achieved mainly by reduced manufacturing time. The time from setting to stretching was reduced from 170 ± 8 min for the MCNB method to 114 ± 12 min for the SCNB method.

Effect on Other Chemical Components. The fat on a dry weight basis of the cheese (Table 1) was also within the target range of 30 to 45% (7). Based on comparisons with fat content of standardized milk used in commercial

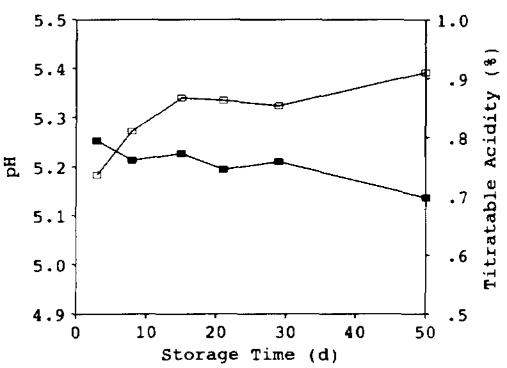

Figure 2. The pH (■) (SEM = .018) and titratable acidity expressed as percentage of lactic acid (□) (SEM = .028) of stirred curd, no brine Mozzarella cheese during 50 d of storage at 4°C.

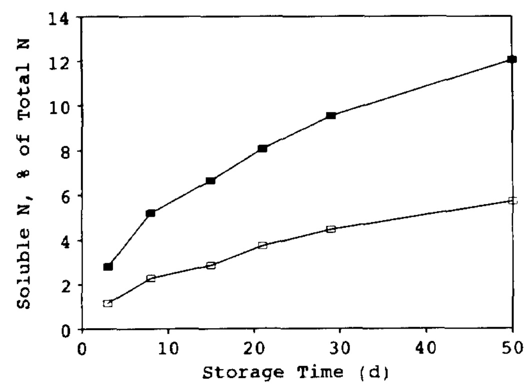

Figure 3. The nitrogen that is soluble in acetate buffer at pH 4.6 (■) (SEM = .11) and in 12% TCA (□) (SEM = .34) during 50 d of storage of stirred curd, no brine Mozzarella cheese at 4°C.

Mozzarella cheese factories a fat on a dry weight basis of 38.2 ± 1.1% starting with milk containing 2.09 ± .08% fat indicates that fat recovery in the cheese was equal to or better than that achieved in commercial factories. The average fat recovery in the cheese was 84.2%; fat losses in whey and stretching water were 9.7 and 6.1%, respectively.

The salt concentration in cheese produced by the SCNB method was 1.76 ± .08%, even with the reduction in the rate of salt usage at dry salting and in stretching water, relative to the MCNB method (Table 1). The calcium content of the cheese was .69 ± .04%, which was lower than the .83 ± .03% for cheese produced using the MCNB method. The lower calcium may be due to the lower pH of whey at draining whey (i.e., pH 6.20) employed in the SCNB method. However, the values are still within the normal range of commercial LMPS Mozzarella cheese (15, 25).

Changes During Refrigerated Storage

Cheese pH decreased, and cheese titratable acidity increased slightly, during 50 d of refrigerated storage (Figure 2). The starter bacteria may have been active during storage and produced a small amount of acid. Nitrogen that was soluble in acetate buffer at pH 4.6 and in 12% TCA increased with refrigerated storage time (Figure 3). These changes were caused by the residual coagulant (27) and starter culture enzymes (4) and affected the functional properties of Mozzarella (28).

The hardness of unmelted cheese by texture profile analysis decreased during storage. In general, the changes in hardness with time (Table 2) were comparable with the results of other studies (24, 28). As storage time increased, melted cheese functionality changed: meltability increased, apparent viscosity decreased, and the amount of formation of free oil increased initially and then decreased slightly (Table 2). Overall, functional characteristics of the melted cheeses were similar to those of commercial and experimental LMPS Mozzarella in previous reports (14, 15, 28). During the first 2 or 3 wk of storage at 4°C, the a color value of baked SCNB Mozzarella increased (Table 3) (i.e., became more brown), as reported previously (6, 20).

Significance to Industry

The problems associated with brine salting during manufacture of Mozzarella cheese can be eliminated by the SCNB method. The uniformity of moisture and salt content throughout large (i.e., 20 kg) and small sizes (i.e., .5 kg) of Mozzarella cheese can be improved. Thus, industry can produce cheese with homogeneous chemical composition, which results in similar proteolysis within and among blocks of cheese from a vat. The challenge still remains for industry to improve

TABLE 2. Functional characteristics of Mozzarella cheese during storage at 4°C (n = 3).

Storage time	TPA[1] Hardness	Meltability	Apparent viscosity	Free oil
(d)	(N)	(mm)	(Pa·s)	(%)
3	71.1	47.5	4072	2.79
8	60.4	48.2	2735	4.13
15	57.1	49.7	1500	5.34
21	55.2	49.9	962	5.38
29	45.4	52.3	615	5.58
50	47.7	52.0	256	4.38
SEM	6.9	1.8	308	.18
LSD	21.1	5.4	950	.56

[1]Texture profile analysis.

process control to reduce variation across days and vats in cheese composition.

In addition, the microbial contamination that occurs during brine salting can be eliminated, thus allowing consistent production of the cheese with improved bacteriological quality. Filtration, sterilization, and disposal of used brine is unnecessary, which may reduce the cost of cheese making. However, small amounts of whey and stretching water contain a low concentration of salt that needs to be processed or removed. Therefore, environmental problems can be minimized. The traditional brine-salting method requires extensive handling of blocks of cheese to place them into brine and to remove them. With the SCNB method, the labor costs during cheese making may be reduced because the blocks of cheese do not need to be handled as much. The SCNB method can simplify cheese making and eliminate the need for milling the curd. This simplified process may make possible the development of a more sanitary and continuous design in equipment for making Mozzarella cheese.

TABLE 3. Color indices for browning characteristics of baked Mozzarella cheese (n = 3).

Storage time	L	a	b
(d)			
3	66.9	−1.39	24.9
8	66.3	.70	27.2
15	65.2	4.56	29.2
21	64.2	4.44	27.1
29	67.3	3.89	28.9
50	70.7	2.41	28.5
SEM	1.6	.64	.5
LSD	5.0	1.98	1.4

CONCLUSIONS

The SCNB process for Mozzarella cheesemaking was developed. Cheese moisture content was significantly higher than that achieved using the previous MCNB method, and overall chemical composition was within the appropriate range for the LMPS Mozzarella cheese. Changes in proteolysis and functional properties during the refrigerated storage were similar to those in commercial LMPS Mozzarella cheese.

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Assessment: Identification of Milk Off-Flavors Quiz

You will be given 5 milk samples to score. Taste a sample of milk and identify the defect. Then score milk based on intensity of the off-flavor. You will get 2 points for each correctly identified off-flavor (10 points total).

Name____

Date____

Potential Causes of Off-Flavor

Flat/Watery	Tastes like skim or 1% milk
Salty	Caused by excess sodium in milk
Malty	Gained by cereal
Metallic/Oxodized	Due to milk going through a rusty container or being exposed to sunlight
High Acid	Due to an excess of butter in the milk
Bitter	Due to cow eating a bitterweed

For each milk sample (scores range from 1-10)

Defect in Flavor	Slight Defect Score	Definite Defect Score	Pronounced Defect Score
No Defect			
Flat/Watery			
Salty			
Malty			
Metallic/Oxodized			
High Acid			
Bitter			